3-Color Micro-LED Integration for Flexible Display Based on Die-First Fan-Out Wafer-Level Packaging Technology

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1. Introduction

Flexible displays have various advantages such as thin structure, light weight, and excellent pliability. Typical flexible display fabrication is divided into two categories: roll-to-roll and transfer processes. In the former roll-to-roll process, optical devices and interconnections are deposited or printed directly on plastic substrates. However, the plastic substrates are plagued by the difficulty of handling during the fabrication process. Recently, most flexible displays are fabricated with organic light emitting diode (OLED) devices. On the other hand, inorganic micro-LED devices shows higher efficiency/brightness and longer lifetime, compared to OLED. However, micro-LED displays are facing two challenging problems. The first one is the transfer of the micro-LEDs, and the second one is the packaging of the tiny micro-LED dies. In this study, we employ a fan-out wafer-level packaging (FOWLP) methodology [1] and demonstrate the integration of 3-color micro-LED dies embedded in an elastomer PDMS as a substrate to fabricate a micro-LED flexible display.

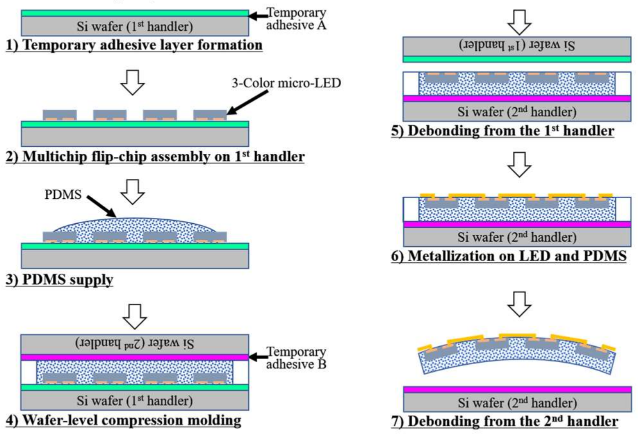

Fig. 1. Process flow of FOWLP with micro-LED dies.

2. Implementation

Figure 1 shows the fabrication flow of a flexible micro-LED display using die-first FOWLP. First, alignment marks were formed on the 1st handling wafer by using standard photolithography processes. Then, the array of 200-µm-thick 3-color micro-LEDs dies (650 µm in a side) was precisely aligned and assembled on a temporary adhesive A formed on the 1st handler. After that, PDMS precursors were supplied on the micro-LED dies, and subsequently cured at room temperature with the 2nd handling wafer (2nd handler) having another temporary adhesive B by wafer-level compression molding. After debonding the 1st handler, all micro-LEDs dies were planarized without any mechanical processes such as CMP, followed by metallization with PVD-Au or electroplated Cu on the PDMS. Finally, the 2nd handler was debonded to give a 3-color flexible micro-LED display.

3. Result and discussion

Figure 2 shows the photomicrographs of top and bottom surface of the 3-color micro-LED die and the schematic view of a 3-color flexible micro-LED display attached on a cylinder. The micro-LEDs are embedded in PDMS and interconnected with 70-µm-wide fan-out wirings. The flexible display is translucent, stable at room temperature, and bendable enough to perfectly follow a human wrist with a curvature radius of 20 mm or less. The total thickness is 500 µm and the 650-µm-square and 200-µm-thick micro-LED dies are aligned with a pitch of 1 mm. The design of the wiring are two layers to connect all the four contacts in a micro-LED die. The multi-level metallization allows basic operation of the 3-color flexible micro-LED display. In this presentation, several issues, dishing, die-shift, and stress accumulation, required to be solved for this flexible display integration are discussed. The biggest advantage of this methodology is that all processes are done at the wafer-level and die bonding/wire bonding or flip-chip bonding is not required for inter-chip connection.

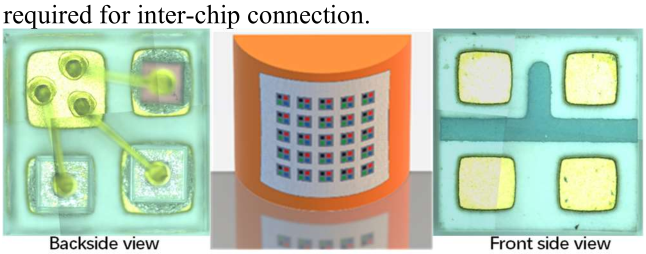

Fig. 2. Schematic view of 3-color micro-LED display.

4. Summary

This work proposed a method for fabricating flexible micro-LED displays based on die-first FOWLP. A flexible display with embedded 3-color micro-LED dies in PDMS was successfully integrated.

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References

[1] Takafumi Fukushima *et al.*, *IEEE Trans. CPMT*, Vol. 8, pp. 1378-1746 (2018).